

Edible Insects and Their Uses in North America; Past, Present and Future



Marianne Shockley, Julie Lesnik, Robert Nathan Allen,
and Alicia Fonseca Muñoz

Abstract Insects have been an important part of food culture for many different places and peoples across North America’s history. This chapter retraces the indigenous uses of insects as a food across the continent, through modern Mexico and into the present day movement to bring these ingredients into the culinary landscape of the United States of America and Canada. The authors provide an overview of the practices and uses of insects as food in both whole and traditional forms, and newer abstractions of the insects into consumer facing snack food products. In addition, the ways in which these startup farms and product makers are using insects for food are discussed, including facets such as crowdfunding, processing and marketing, as well as evidence from the culinary and celebrity worlds that entomophagy is gaining traction in North America.

1 Introduction

Insects have never been considered part of the traditional American diet, but the practice is not completely absent from North American history. The “American” diet we think of today is one of great European influence; prior to colonization, numerous diverse tribes of indigenous peoples inhabited the continent. For some of these groups, edible insects were an important part of their lives. Most of our understanding of how these insects were consumed comes from the recorded observations

M. Shockley (✉)
University of Georgia, Athens, GA, USA
e-mail: entomolo@uga.edu

J. Lesnik
Wayne State University, Detroit, MI, USA
e-mail: julie.lesnik@wayne.edu

R. N. Allen
Little Herds, Austin, TX, USA

A. F. Muñoz
Instituto Politecnico Nacional, Oaxaca, Mexico

of anthropologists as well as non-academics, such as explorers. The earliest accounts are especially biased, placing European values on the cultural norms of indigenous people. In these writings, indigenous people are described as primitive, savage, and animal-like (see Morgan 1877). The practice of eating insects therefore was either a part of this savagery, or only something done when no other food choices remained (Schrader et al. 2016).¹ Today, many people, such as chefs, entrepreneurs (Shockley et al. 2017), academics, and more, are working to promote insects as a healthy and sustainable food source and help get people past these stigmas. This chapter reviews insect eating across the continent of North America, with primary focus on continental United States and Canada. We begin with a history of indigenous use of edible insects, which is one that has been mostly lost post colonial settlement. We then look at a more recent history of the academic interest in edible insects beginning in the latter part of the twentieth century, and continue on to the resurgence of interest in the twenty-first century, assessing the current movement to get more people to eat insects and a projection of what the future holds.

2 Indigenous History of Insect Eating

Prevalence of insect eating is variable around the globe; one factor behind the pattern is that not all environments are conducive for producing edible insect options. The tropics offer the most biodiversity, and it is well documented that insect consumption is much more prevalent in tropical countries than others (Van Huis et al. 2013). As latitude increases away from the tropics, insect eating reduces (Lesnik 2017). For instance, all European countries are located at latitudes north of the subtropics, and for the first inhabitants of these areas, hunting was the only way to survive the harsh winters (Leonard 2003). Today, domesticated animals have replaced large game in most European diets, and this reliance on meat reduces the likelihood of insects being consumed since they have similar nutritional offerings.

2.1 Canada

In North America, ecozones vary greatly. Almost the entire country of Canada, like most of Europe, resides past the 45th parallel, which is the halfway point between the equator and the North Pole. The environments here typically undergo large seasonal temperature differences, and accounts of insect consumption by First Nations Peoples are limited. Caribou hunters, such as the Tłı̨chǫ (or Tlicho) of the Northwest Territories, ate warble fly larvae, which was a byproduct of their hunting (Felt 1918). The larval form of this parasitic fly species can often be found in abundance

¹For a more in-depth review of North American edible that includes taxonomic designations, see: Schrader et al. (2016).

when butchering caribou. It is documented that the Tł̨ch̨q̨ valued these larvae for their taste and would often leave them in place to develop further before eating them raw (Hearne and Tyrrell 1795; Russell 1898). In the east, the Wolastoqiyik (also known as Maliseet) of New Brunswick used black ants as a source of food and medicine (Schrader et al. 2016). Ants even made their way into the diets of some settlers, with reports of lumberjacks in Québec (and Maine in the U.S.) who would catch and eat carpenter ants (Schrader et al. 2016).

2.2 *Mexico and Latin America*

The country of Mexico straddles the Tropic of Cancer, placing it in the tropics and subtropics. Traditional Mexican cuisine is rich with edible insects, and in fact, Mexico is one of the world's leaders in insect consumption with over 300 known insect species commonly consumed (Ramos-Elorduy 2009; Jongema 2017). In the context of edible insects, Mexico is better classified as Mesoamerica or Latin America because of the vast climatic and cultural differences between this country and its northern neighbors.² However, Mexican culture has not gone without Western influence. Even in the state of Oaxaca, where chapulines (toasted grasshoppers) are celebrated as a symbol of Oaxacan identity (Thrussell 2016), by the late 1960s, there was growing tension surrounding foraged foodstuffs as they lacked prestige (Wilken 1970). Today, younger generations consider chapulines a traditional dish; something that is popular with the elderly and a symbol of rural life that may be useful in a moment of crisis, but mostly to be eaten as part of a celebration of culture (Cohen 2004; Grieshop 2006).

2.2.1 *Diversity of Edible Insect Species*

Mexico is a country characterized for being biologically rich and culturally diverse. Since ancient times, the practice of collecting insects for human consumption (entomophagy) was very common in many rural areas. Entomophagy in Mexico is believed to have been practiced before Spanish conquest (Christenson 2007). Native people used to collect the insects from the land and water. The tradition and preparation of insects have been kept alive in rural communities through many generations up to the present.

In Mexico, between 504 and 535 species of edible insects have been recorded (Ramos-Elorduy et al. 2006; Costa-Neto and Ramos-Elorduy 2006). Most of these species are collected from terrestrial ecosystems and few species from aquatic ecosystems. All these species are collected including different stages of their

²For a more thorough review of entomophagy in Mexico, see the works of Julieta Ramos-Elorduy. Also of note is volume 2(1) of *Journal of Insects as Food and Feed*, which is a special issue dedicated to Latin America.

biological development (eggs, larvae, nymphs and adults). Thus, in Mexico, 13 orders are reported: Coleoptera, Lepidoptera, Hemiptera, Diptera, Hymenoptera, Orthoptera, Homoptera, Ephemeroptera, Odonata, Trichoptera, Anoplura, Isoptera and Megaloptera (Ramos-elorduy and Viejo Montesinos 2007). Among the orders with greater consumption is Coleoptera, Himenoptera, Ortopteros and Lepidoptera.

The order Coleoptera Ramos-Elorduy and Pino Moreno (2004) reported 126 species in 18 states in Mexico. The most abundant family was Melolonthidae followed by Cerambycidae, Dytiscidae, and Passalidae. Families with most edible genera are Cerambycidae, Melolonthidae, Passalidae, Dytiscidae, and Tenebrionidae. Among some states in Mexico where edible insects have been reported are Chiapas, Oaxaca, Mexico, Hidalgo, Guerrero, Queretaro, Campeche, Guanajuato, Tabasco, Puebla, Jalisco and Michoacan (Ramos-Elorduy et al. 1997; Ramos-Elorduy and Pino 2006, 1998).

2.2.2 Entomophagy in Estado de Mexico

Estado de Mexico is one of the 31 Mexican states located in the center of the country next to Mexico city. In this state, there is a record of 104 species of edible insects (Ramos-Elorduy et al. 1998). The most consumed are Hymenoptera, Orthoptera, Hemiptera and Coleoptera (Ramos-Elorduy et al. 1998). Native people from Estado de Mexico practiced entomophagy even before the Spanish conquest. Nowadays, it is a common practice and commercialized by some companies. For example, one of the regions of the Estado de Mexico, specifically in Santo Domingo, Axapusco, is known for the collection of honey pot ants (*Myrmecystus mexicanus*). This kind on ants produce honey and are very attractive for consumption and commercialization because of its nutritional and medicinal properties (Ramos-Rostro et al. 2009).

2.2.3 Entomophagy in Oaxaca

Oaxaca is one of the states where insects are most consumed. It is a multicultural state rich in indigenous traditions, myths, customs, beliefs and ethnicities (Ramos-Elorduy et al. 1997). Insect consumption is very common in this state, the main insect orders reported so far are Anoplura, Diptera, Orthoptera, Hemiptera, Homoptera, Lepidoptera, Coleoptera and Hymenoptera (Ramos-Elorduy et al. 1997). Insects that are most consumed are chapulines (Orthoptera), maguey worms (Lepidoptera), chicatanas and escamoles (Hymenoptera) among others. Insects are sold in markets, restaurants, and companies. The top-selling insects are grasshoppers, followed by mescal worms and ant's eggs. In the market, the sellers (mostly women) mainly sell grasshoppers of different sizes and flavors (lemon, chile, and garlic) and maguey worms among others. The sale of insects is given by varying measuring units that have preference among different merchants (fist, pots, grams). As for the commercial companies, Inalim is a Oaxacan company that

sells products at national and international level prepared with chapulines *Sphenarium purpurascens* and maguey worms. Some of its products are the sauce of chapulin with 12 flavors and salt of chile prepared with maguey worms, which can be accompanied by a mescal. On the other hand, restaurants usually have their menu based on foods prepared with chapulines such as mole, tlayudas, tamales and stuffed peppers among others. In times of rain, people go out to collect the chicatanas “flying fleas” or “flying ants” which are consumed mainly in sauces and mole. It is worth mentioning that chicatanas are considered a luxury dish, due to the high cost in the market.

2.3 *United States of America*

The United States represents the transition between these two very different climates. In the southeast, the climate is subtropical, in the southwest it is semi-arid or desert, the western seaboard is Mediterranean-like in climate, while the northeast and Midwest experience the great variation in seasonal temperatures associated with northern latitudes. Therefore, prevalence of edible insects varies greatly across these regions.

2.3.1 **Great Basin**

Insect consumption was most prevalent, or at least best documented, for Native Americans of the Great Basin region. This area west of the Rocky Mountains is a closed drainage basin that retains water and allows no outflow; therefore salts and other dissolved minerals accumulate in lakes such as the Great Salt Lake or Mono Lake (Hammer 1986). Insects, such as drowned grasshoppers and the pupae of shore flies, can be easily collected on the shores of these lakes while already being naturally salted (Sutton 1988; Madsen and Schmitt 1998; Ebeling 1986; Schrader et al. 2016). However, this is not the only way insects were consumed in the Great Basin. In their review of North American entomophagy, Schrader and colleagues offer these other examples for the region: June beetles being caught and fire roasted (Sutton 1988), swarms of Mormon crickets driven into trenches that were then set on fire (Egan and Egan 1917), carpenter ants collected, dried, and ground into flour (Steward 1943), and Pandora moth caterpillars being wrangled at the base of trees by way of dug trenches (Aldrich 1921).

Much of what we know about entomophagy in the Great Basin and other arid regions of California, Nevada, and Arizona, comes from archaeological contexts (Sutton 1995). Dry environments promote easier preservation of organic matter, so the likelihood of finding archaeological evidence of insect consumption is greater in these localities. Also, the topography of this region includes numerous caves, which were natural shelters for people, but also aided in the preservation of artifacts. Food caches containing grasshoppers have been uncovered from Mantles

Cave in northwest Colorado (Burgh and Scoggin 1948) and Crypt Cave in northwestern Nevada (Orr 1952). These dry and protected conditions are also suitable for recovering preserved human feces known as coprolites. At Dirty Shame Rockshelter in southwest Oregon, termites of the *Reticulitermes* genus made up 78.3% of one of the coprolites. At Bamert Cave in east-central California, crane flies made up 25% of a coprolite. In the Glen Canyon area in southern Utah, the amount of insect remains that show up in coprolites increases over time, although the authors state that they never formed a major component of the diet.

2.3.2 Southeast

In the southeast, the semitropical environment suggests that this region should be the most conducive to edible insects. However, there are only limited records. In Brickell's (1737) account of the natural history of North Carolina, he mentions that the "Indians" ate wasp larvae from the combs. Although the tribe is unnamed, it is possible they were Cherokee, and that Carr's (1951) account of the Cherokee digging yellowjacket larvae from their nests is relaying the same cultural practice. The humid environment of this region is not conducive to the preservation of organic materials like that of the Southwest; however, two cave sites with remarkable preservation give some insight to insect consumption. A mummified body found in a rockshelter in the Ozark Mountains preserved insect parts along with other food items in its feces contents (Wakefield and Dellinger 1936) and another mummy, along with additional coprolites, recovered from Salts Cave Kentucky contain small quantities of insect cuticle, indicating their consumption (Yarnell 1974).

2.3.3 Midwest and Northeast

There are accounts of the utilization of edible insects in the Midwest and Northeast, even though these environments may be considered less suitable for edible insects. The now extinct Rocky Mountain locust that inhabited the arid land to the east of the Rocky Mountains was consumed in great numbers by many indigenous peoples as far east as Iowa and the Dakotas until the early part of the twentieth century. The Assiniboine of the Northern Great Plains would round up swarming locusts into open pits for collection (Berenbaum 1996). Periodical cicadas, which emerge in large numbers every 17 years in the northern states of the eastern U.S., provide a feast when they are available. The earliest written account of people eating cicadas comes from a journal entry dated Sandel 1715 written by Reverend Andreas Sandel, rector of the Swedish congregation in Philadelphia, Pennsylvania. He describes how these "flies" emerge from the holes in the ground, and that pigs, poultry, and even some people ate them before they disappeared only a short while later. People today still take advantage of cicadas when they emerge; it is possible to find many different recipes for their preparation online. Use of this periodic resource is a rare example of an edible insect that transcends the lines drawn between indigenous and colonial culture. This may be a beacon of hope for the future of edible insects in the United States.

3 Entomophagy in the Twentieth Century

The “Godfather” of modern entomophagy in North America was the late Dr. Gene DeFoliart at the University of Wisconsin, Madison. One of DeFoliart’s legacies includes *The Insects as Food* website is a reservoir of information and scholarly literature produced by DeFoliart from the 1970s through the 2000s (February, 2017). This website, currently housed at the University of Wisconsin, holds peer reviewed publications of Dr. DeFoliart, his colleagues and his graduate students as well as a working worldwide bibliography of all of the edible insects published in the academic literature to date. This online resource is invaluable for piecing together the edible insect and entomophagy literature and more precisely the individual species of edible insects that have been recorded in the scholarly literature to date. The *Insects as Food* website is, to date, the most comprehensive bridge of research from the early twentieth century to the modern era of the entomophagy movement.

3.1 *Food Insects Research and Development Project*

The Food Insects Research and Development Project (FIRDP) was organized at the University of Wisconsin in Madison in 1986, primarily as a set of objectives aimed at stimulating a wider awareness among food and agricultural scientists, government agencies, and the public that insects are a food resource that warrants serious investigation. The deeply rooted traditions of food insect use among many, if not most, ethnic cultures of non-European origin provide an existing base upon which to build-from the bottom up, as opposed to the usual direction of innovation from the top down (Defoliart 1989).

Public reeducation is also being advanced by a proliferation of public events featuring or including edible insects, such as open houses or field days sponsored by zoos, nature centers, state fairs, museums, universities, and professional societies. Details on such events, many of which are held annually, can be found in the pages of *The Food Insects Newsletter*, which began publication in 1988 and has proven valuable as an international forum and networking mechanism for researchers, educators, and others having an interest in the subject. While the public information advances are important, even more important is the apparent foothold that the subject is gaining in the US educational system (Defoliart 1999).

3.2 *Food Insects Newsletter*

In 1988, North American entomophagy was localized as the academic newsletter “*The Food Insects Newsletter*,” edited by DeFoliart at the University of Wisconsin. Dr. DeFoliart and a group of interested graduate students and colleagues submitted articles published three times a year, from 1988 until 1995. Each edition of the newsletter featured several different authors from North America and around the world. Some of the submissions featured incidents of entomophagy in early Native

American cultures. Others submissions were of recipes or events where edible insects were served. Upon Dr. DeFoliart's retirement the newsletter ceased. In its place was a informative website "Insect As Food," edited and managed by DeFoliart, entomologist Dr. Florence Dunkel (a previous graduate student of DeFoliart's) of Montana State University and Entomophagy advocate and historian David Gracer. Although new articles were not being submitted, Dr. DeFoliart utilized the expansion of technology and the internet to make all of the articles of the Food Insects Newsletter available online. By making this information freely available online, there seemed to be a rapid expansion of westerners knowledge of entomophagy. Prior to this, individuals had to know of and be subscribed to the Food Insects Newsletters, which were relegated to academia and delivered in a printed issues several times a year. With the offering of hundreds of edible insect related articles online, further interest in entomophagy expanded. In the 1980s and early 90s, entomophagy advocates in the United States such as David Gracer and David George Gordon, *The Bug Chef*, appeared more commonly in the mainstream media including newspapers, magazines, and television. Books like David George Gordon's "Eat-A-Bug Cookbook," became available for those curious about edible insects, along with "Man Eating Bugs," by Faith D'Aluisio and Peter Menzel, and "Creepy Crawly Cuisine; The Gourmet Guide To Edible Insects," by Dr. Julieta Ramos-Elorduy.

3.3 Modern Edible Insect Use in Mexico

In Mexico, the use of insects for cooking has increased through the last few decades, and the diversity of dishes made with insects makes them increasingly accepted in society. The use of insects in food in rural areas plays an important role in the nutrition and economy of many indigenous peoples, but in restaurants, the costs are higher and thus still prohibitive. Without established standards of best practice and precise regulations, there is potential for over-harvesting and exploitation of the wild insects. Already species like the Chicatana Ant are becoming endangered as natural habitats are lost to development and more wild-crafters over-harvest the insects. Thus, domestication practices will be critical to Mexico's edible insect industry.

4 Edible Insects in the Twenty-First Century

Early in the 2000s, Dr. Florence Dunkel reached out to fellow edible insect advocates and published a book of all of the editions of the Food Insects Newsletters, providing a crucial resource to researchers interested in entomophagy. In 2008 the Food Aid Organization of the United Nations hosted a conference, "Forest insects as food: humans bite back" in Chiang Mai, Thailand, attracting scientists from all over the world to present, learn, and share information about insects as food in

different cultures, communities, and countries worldwide. In retrospect, this event was a likely catalyst for the current entomophagy movement that we are experiencing from 2013 to the time of writing, 2017. Several North American edible insect advocates and researchers presented at this conference, and the event spurred a resurgence in worldwide focus and a shift towards thinking of insects as a nutritious and environmentally friendly food source.

4.1 Academic Interest Accelerates in North America

In 2009, a researcher at the University of Georgia (co-author Marianne Shockley), was contacted by a group in Alabama that was interested in hosting an International Edible Insect Conference. The query from the conference host was to report on the status of entomophagy in higher education. Representatives consisting of world renowned edible insect researchers, advocates, academics, and representatives from the FAO and other governmental organizations met to showcase the status of edible insects globally. One particular presentation request directed at entomologists in the U.S. was to determine the status of entomophagy in American Higher Education. It was presented that although edible insects appear as a lecture topic in a course at various institutions across the U.S. there was not a single, stand-alone university course dedicated to entomophagy. Entomologists and other academics were just not teaching and sharing information in universities and colleges across the U.S. about entomophagy to the degree seen elsewhere; the worldwide entomophagy movement had not yet trickled into science departments in the U.S.

Later in 2010, a Program Symposium was included in the Entomological Society of America Annual Meeting in San Diego, CA. “Entomophagy Reconsidered: Current Status and Challenges, Potential Directions, and an Invitation to Entomologists”. At this symposia, former students, colleagues, and advocates of Gene DeFoliart’s edible insect research presented about the current status of entomophagy in the U.S.

4.2 Shifting Popular Perceptions to Value Insects

Despite the growing excitement within small cadres of academics, by 2010 the idea of eating insects was still strange to most people in Canada, the United States and large swaths of Mexico and Latin America, outside of reality TV challenges and gameshow stunts like Fear Factor and Survivor. Even though there is extensive historical evidence of the traditional use of insects as food in indigenous cultures across the Americas, the Western food culture had long ago forgotten about insects as food. The idea was at best a novelty but more often a cultural and psychological taboo; revolting to the average consumer.

In 2010 something changed. As if in tandem with broader public discourse about food safety, transparency, corporate accountability, nutrition and climate change, small groups of advocates and entrepreneurs across the continent realized they had to shift the conversation on entomophagy. The goal was to push the public perception of insects away from gross gag gifts and poor food of desperation, and towards recognition as a nutritious and exciting ingredient. These organizations and companies began touting the benefits of bugs in a whole new way, focusing on the environmental and nutritional benefits as source of pride.

While insects as a novelty item had been around for decades through candy companies like Hotlix, these products like scorpion lollipops, candy-coated ants and chocolate-covered crickets were sold almost exclusively as gag-gifts. These products offered no information on the nutritional and environmental benefits insects as a food could provide, and weren't positioned as a food item a consumer would actually incorporate into their diet on a regular basis.

4.2.1 Abstraction for Hesitant Western Consumers

This all changed when the idea of “cricket flour,” was first popularized by World Entomophagy, a startup company founded in 2010 in the dorm-room of University of Georgia student Harman Singh Johar (a student of co-author Marianne Shockley). World Entomophagy was the first USA company to publicly market insects ingredients specifically for human consumption, selling mealworms, whole crickets and cricket powder (billed as “cricket flour,” these terms were often used interchangeably until 2015) directly to consumers. World Entomophagy began with Johar rearing crickets in his closet as an entomology student, baking them, grinding them, packaging them and shipping them off to waiting customers. Over the next 2 years World Entomophagy grew, moved to Austin, Texas in 2013 and was acquired by Aspire Food Group in 2014.

4.2.2 First Consumer Products

In 2012, capitalizing on the potential of abstracting insects for hesitant western consumers, Salt Lake City based Chapul was the first company to offer a snack product, protein bars, made with “cricket flour,” crickets dried and ground to a fine powder. (What was then called “cricket flour” is now referred to as “cricket powder” by most companies in the industry. Cricket Flour on the other hand now commonly refers to a baking flour blend, combining insect powders and other flours for an easy baking substitution) It took Chapul 8 months to secure a cricket supply and a commercial kitchen, refine their recipes and work with regulators to take their unconventional product to market. Launching on crowdfunding platform Kickstarter, Chapul's founder Pat Crowley raised \$16,065 to begin production of the first line of cricket protein bars, which would soon become eponymous with

the entomophagy movement's push into the public view. At this time, there was still very little understanding to how insects would be regulated as a food, as there was little regulatory precedent outside of the cochineal beetle used for red dyes, and the mention of insects in the maximum allowable defect limits the FDA specifies for processed foods. "Our product was a first-of-a-kind, so we had to provide lab test results that showed our cricket flour, and the food we were feeding the crickets, were safe for human consumption," Regarding their crowdfunding, "We were surprised at how much interest it got. We had donors from 13 countries," Chapul used took the crowdfunding success and started their web presence and online store and purchased ingredients in bulk for their initial manufacturing run of cricket protein bars.

4.3 From Academia to the Popular Imagination

In 2012, the FAO held an Expert Consultation "Assessing the Potential of Insects as Food and Feed in Assuring Food Security" in Rome Italy, with the support of the Government of the Netherlands. This expert consultation consisted of international experts and entrepreneurs from around the world, specializing in varying aspects of insect rearing, plant protection and food engineering, and resulted in lively discussions with FAO experts from different backgrounds and disciplines. Soon after, a follow-up storm of public media press ensued discussing the idea of entomophagy critically. Popular press publications went from a few publications a month to a few publications each week (Shockley et al. 2017).

Additional international conferences and collaborations continued to inspire, motivate, and inform edible insect and entomophagy research in North America. Following the 2013 Expert Consultation in Rome, the FAO produced a follow up publication, "Edible insects: future prospects for food and feed security," sparking an interest among English language media outlets and a groundswell of publications from the popular press. "Edible insects: future prospects for food and feed security," is the most downloaded document that the FAO has ever had, at more than 7 million public downloads. The FAO report identified three main reasons for promoting the eating of insects: insects are healthy (high zinc, iron, calcium and protein), insect harvesting is environmentally benign (reduced greenhouse gas emissions and less land), and workforce creation with insect harvesting (low-tech, low-capital). In August of 2013 an interdisciplinary conference, "Poeticizing the Urban Apparatus: Scenes of Innovation, Translating Entomophagy Panel" was hosted in New York City. Following the panel was a Future Food Salon (FFS) hosted by Alimentary Initiatives and the Culture of Cities Centre. Having hosted the first FFS in Toronto focused on edible insects earlier that year, Alimentary Initiatives hosted a third FFS with Little Herds in Austin, Texas in 2014 and a final FFS in Montreal in 2015.

4.4 Crowdfunding

In 2013, following Chapul’s initial success in crowdfunding, startup Exo also took to crowdfunding with overwhelming support. The use of crowdfunding to launch an insect product would quickly become a mainstay of the industry, and was an interesting exception in the world of consumer packaged goods (CPGs). While many industries and food trends are started by large corporations and conglomerates that see potential profits, the edible insect industry was pushed into the mainstream by startups with nothing but passion and the public’s support. At the time of writing, early 2017, no large food companies have acquired an insect product company, and no large companies have created products with insect ingredients (beyond products containing cochineal as a dye and the aforementioned novelty candies). Since 2012, there has been a steady increase in the number of successful crowdfunding campaigns launching new insect products to the market (Fig. 1), showing that the public supports the idea of insects as food with their purchasing power.

Timeline of Edible Insects Crowdfunding	
2012	Chapul, USA: Raised \$16,065 from 372 backers
2013	Exo, USA: Raised \$54,911 from 1,241 backers
2014	Six Foods (Chirps), USA: Raised \$70,559 from 1,295 backers Hopper Foods, USA: Raised \$34,523 from 479 backers
2015	Crickers, USA: Raised \$33,250 from 406 backers Krik Nutrition, Canada: Raised \$16,428 from 191 backers Coalo Valley Farms, USA: Raised \$3,173 from 23 backers CrittterBitters, USA: Raised \$23,627 from 438 backers (w/30hrs left) <i>CroBar, UK: Raised \$10,227 from 111 backers</i> Crowbar’s Jungle Bar, Iceland (produced and distributed in USA/Canada): Raised \$27,806 from 23 backers Megan Curry’s #BugWall, USA: Raised \$2,051 from 29 backers
2016	Livin Farms Hive, USA and Hong Kong: Raised \$145,429 from 830 backers Eat Grub Bar, UK: Raised \$13,032 from 116 backers EntoBento, USA: Raised \$16,001 from 225 backers Bugs On The Menu, Canada: Raised \$2,044 from 49 backers The Gateway Bug, USA: Raised \$19,855 from 232 backers <i>Butterfly Skye’s VitaBug, Australia: Raised \$3,282 from 27 backers</i> OneHop Kitchen, Canada: Raised \$6,376 from 134 backers MealFlours, USA and Guatemala: Raised \$16,120 from 244 backers Little Herds, USA: Raised \$10,597 from 111 backers <i>Jimini’s, France: Raised \$23,651 from 346 backers</i> <i>Sens Bar, Germany: Raised \$13,888 from 290 backers</i> Sidiki Sow, Canada: Raised \$9,908 from 68 backers Lithic Nutrition, USA: Raised \$12,160 from 169 backers
Total North American crowdfunding through 2016: \$520,983	

Fig. 1 Crowdfunding; amounts raised and number of backers for North American companies through 2016 (companies outside of North America denoted in Italics and not included in the total)

4.5 *From Ideas to Production*

Continuing this global momentum, in 2014 the “Insects To Feed The World” conference was organized in collaboration between Wageningen University and the FAO, and was held in Wageningen, the Netherlands. The conference brought together the largest assembly to date of Insects for Food and Feed stakeholders from all over the world to consider key aspects of collection, production, processing, nutrition, marketing and consumption related to insects in a global multi-stakeholder dialogue. The conference marked an important step towards mobilizing the potential of insects as human food and animal feed to contribute to global food security and in particular to exchange information on the feasibility of mass rearing of insects to increase the availability of animal proteins in a more sustainable way. Several North American edible insect companies and researchers were in attendance.

Following the 2014 conference in the Netherlands, the first North American conference dedicated to edible insects, the “Eating Innovation Conference: the art, culture, science and business of entomophagy” was held at the Montreal Space for Life Botanical Garden and the Montreal Insectarium. This conference was attended by more than a hundred participants engaged in numerous disciplines within the overarching field of edible insects. Organizers hosted The Big Bang Bug Banquet, featured a nine course insect themed meal with accompanying insect infused drink selections prepared in part by chef Cookie Martinez.

In addition to interdisciplinary conferences hosted in the United States and Canada, annual symposia have been hosted at the Entomological Society of America (ESA) Annual Meetings, including ESA 2014 in Portland, Oregon - Insects as Sustainable and Innovative Sources of Food and Feed Production; ESA 2015 in Minneapolis, Minnesota - Synergies in entomophagy: Taking insect eating to the next level; 25th International Congress of Entomology in conjunction with the ESA Meeting 2016 in Orlando, Florida - An Emerging Food Supply: Edible Insects; and the upcoming ESA 2017 in Denver, Colorado - Insects: It’s what’s for dinner.

4.6 *2016, Year of the Cricket*

The first stand-alone academic conference devoted to Insects as Food and Feed in the United States was held in Detroit, Michigan in May, 2016. The Eating Insects Detroit Conference highlighted the current status of entomophagy and featured North American as well as international presenters and an insect dinner in conjunction with startup Detroit Ento. Edible insect expert panelists and keynote speakers gathered for 3 days of seminars, panels, presentations, group discussion and break-out sessions. This conference was the first time many of the North American stakeholders met in person, and was considered a resounding success by attendees as the first conference of its kind in the USA. Keynote speaker Paul Vantomme, recently

retired from the FAO and co-author of the 2013 report on edible insects, proclaimed it to be one of the best conferences he had ever been to. This conference was also the site of the founding meeting of the North American Coalition for Insect Agriculture (NACIA).

4.7 *Entomophagy's First American Trade Association*

The North American Coalition for Insect Agriculture (NACIA) is the first American trade organization dedicated to insects as food and feed and was created in part due to the suggestions of Sonny Ramaswamy, head of the National Institute of Food and Agriculture at the United States Department of Agriculture. Founded by five entomophagy advocates, including co-authors Dr. Shockley and Mr. Allen, the NACIA was designed to be an inclusive and representative association for the fledgling industry. The NACIA held elections open to the public in the fall of 2016 and convened their first Board of Directors at the start of 2017, representing the Research, Business, Education and Regulatory aspects of both Food and Feed insects. The initial Board was comprised of many industry stakeholders, including:

Dr. Marianne Shockley (UGA), Alex Klonick, Amanda Bushell, Darren Goldin (Entomo Farms), Dr. Jeff Tomberlin (A&M), Cheryl Preyer (EnviroFlight), Ikju Park (Bitwater Farms), Travis Dorsey (Bitwater Farms), Robert Nathan Allen (Little Herds), Eli Cadesky (C-Fu Foods, One Hop Kitchen), Jakub Dzamba (Third Millennium Farming) and Julianne Kopf (BugEater Foods).

As an academic and researcher navigating the scientific literature and professional conferences, this author's experience (Dr. Shockley) with this emerging industry was very different than the experiences of the for-profit startups and farms. There seemed to be consistent confusion with local, state and federal health inspectors and agencies in the area of insects as food. Health inspectors are accustomed to identifying insects as pest, nuisance, and defect problems, not being confronted with them as a whole food ingredient. When members of the Insects for Food and Feed Industry collaborated at meetings, barriers and challenges were often points of discussion and sometimes contention, even disappointment. Professionals were expressing and sharing the challenges they had experienced at the local, state, federal and sometimes international level with agents not understanding their business, insects as the primary food ingredient, health and safety standards or protocols. The mission of the NACIA is to be a unified voice for the emerging insects as food and feed industry in North America.

5 Farming

Prior to 2012, no farms in North America grew insects specifically for food. There were however many farms growing insects, especially crickets and mealworms, for use as feed to pets and fishing bait. This provided a template for domestication that

many startups began to refine. Despite this rudimentary template, many of the USA and Canadian insect farms have been heavily focused on automation, as labor costs are still seen as prohibitively high. Updating the practices inherited from the pet-feed insect industry by incorporating robotics, mechanization and automation into the system, as well as sensor technology and data aggregation allows these farms to iterate quickly towards the insect farms of the future. As trailblazers like Next Millennium Farms (now Entomo Farms) in Canada and Big Cricket Farms in the USA began to farm insects for food, more entrepreneurs around the continent followed suit and began small farming operations. These farms have primarily worked with the Common house cricket (*Acheta domesticus*) and the Banded cricket (*Gryllobates sigillatus*). In 2014 Aspire Food Group was the first company in the USA to both farm insects for human consumption and process them into ingredients like cricket powder (Called Aketta Cricket Flour) at their pilot USA farm in Austin, Texas. In 2016, industry giant and established pet-feed cricket farm Armstrong's Cricket Farm announced that they will be converting a small portion of their overall operation to crickets farmed for human consumption, signaling a sea change for other long-time pet-feed insect farms. While Organic Certification in either Canada or USA was initially thought to be insurmountable based on feedback from multiple Organic certification agencies, in 2015 Entomo Farms was the first food insect farm to receive Organic Certification (as well as Gluten-Free Certification) from EcoCert, an international Organic certifier, further establishing expectations and possibilities for consumers and farmers to come.

During this period, 2012–2017 (Fig. 2), there were only a handful of startup insect farms in Mexico working on the domestication of traditionally consumed

As of early 2017, active Food Insect farms in North America include, but are not limited to:

- Entomo Farms
- Tiny Farms
- Rocky Mountain Micro Ranch
- Iowa Cricket Farm
- Aspire Food Group DBA as Aketta
- Ozark Fiddler Farm
- Tomorrow's Harvest
- Seginus Farms
- Cowboy Cricket Farms
- Poda Foods
- *Detroit Ento
- *Big Cricket Farms
- *Coalo Valley Farms
- **Rainbow Mealworms
- **Armstrong Cricket Farm
- **Reeve's Cricket Farm

* Market status unconfirmed at time of writing

** Primarily Feed Insects, but entering Food Insects space

Fig. 2 North American farms actively growing and marketing insects for food as of 2017

insects, none of which have been successful to these author's knowledge. There is however a robust network of semi-cultivators and wild-harvesters who supply a wide variety of insects, especially chapulines grasshoppers and red agave worms, to chefs, product makers and individual consumers alike. The farming of greater mealworms, lesser mealworms, buffalo worms and super-worms for human consumption has not been adopted in North America beyond, to a small degree, Entomo Farms in Canada and Rocky Mountain Micro Ranch, Don Bugito and Rainbow Mealworms in the USA (Rainbow Mealworms farms insects primarily for pet-feed).

5.1 Crickets Over Mealworms

One of the most interesting differences between the North American entomophagy movement and the European counterpart is the preference of crickets over mealworms. It could be that "mealworm," contains the word "worm," and American and Canadian consumers have more negative reactions to the word "worm," than they do "cricket." It could also be that there was an established industry of crickets farmed for fishing bait and pet feed that provided a template for the first American and Canadian farmers to easily adopt when choosing their first insect to farm. More research could be done looking at the data from online searches and social media mentions to see if there's a clearer reason why crickets seem to, for now at least, dominate both the spotlight and the funding sources. Unfortunately we could find no studies addressing the prevalence of crickets in the North American edible insect market at the time of writing.

6 Common Processing Methods

There have been three main processes seen in the North American entomophagy industry for turning raw insects into insect ingredients: Roast and Grind; Slurry, Spray and Dehydrate; and Other.

6.1 Dry Roasting and Grinding

First piloted by early startups like World Entomophagy and Next Millennium Farms (Now Entomo Farms), this process is low impact and easily replicated from large-scale down to the home kitchen. Raw, usually frozen, whole insects are washed and cleaned, then dry roasted in an oven. Industrial convection ovens are often used, but other roasting devices like coffee roasters have been used as well. Once the insects are dried and crispy, they can easily be ground into a fine powder. The advantages here are the initial cost in machinery, which is low, and a smaller energy usage. The

roasting creates a rich brown color in the powder and also brings out the nutty aromas and flavors commonly associated with cricket flour, or powder.

6.2 *Slurry, Spray Dry, Dehydrate*

Piloted by All Things Bugs (now Griopro), this method takes the raw insects and combines them with water in a machine used to slurry the insects. The insect slurry is then sprayed as a fine mist onto trays that can be dehydrated, leaving a very fine powder as the final product. While this process is more energy-intensive, it does have the advantage of producing incredibly fine grains, and the powder tends to be more water soluble. These powders are typically more taste and aroma neutral, and are usually much lighter, almost white in color.

6.3 *Other*

Most recently in 2016, C-Fu Foods has been their piloting patent-pending processes to extract and restructure insect proteins into versatile food ingredients, like soluble protein powders for beverages and textured insect proteins for meat analogues. They have also piloted the use of their textured insect proteins as egg or dairy replacements in baking and food processing applications.

Other companies are working on separation processes to isolate the proteins, fats and chitin out from the raw insects for further specific uses in food, dietary supplements, pharmaceuticals and cosmetics.

7 Regulations, Investments and Marketing Trends

In order for this industry to grow successfully, many logistical hurdles are still being addressed. Without clear regulations, infrastructure investment is hesitant and risk-averse. Without investment into production and processing, insect ingredient costs remain high and research is limited. Finally, without regulatory clarity and investment for production, any positive marketing trends regarding perceptions of insect products cannot be capitalized upon.

7.1 *Regulatory Landscape*

While the growing industry was actively in communication with the USA's Food and Drug Administration (FDA), United States Department of Agriculture (USDA) and Health Canada (Canadian Food and Drugs safety authority) about



"Under the Food, Drug, and Cosmetic Act as amended, bugs/insects are considered food if they are to be used for food or as components of food (Sec. 201(f)).

Usually, all that the FDA requires under the law is that the food must be clean and wholesome (i.e. free from filth, pathogens, toxins), must have been produced, packaged, stored and transported under sanitary conditions, and must be properly labeled (Sec.403). The label should include the scientific name of the insect.

In the case of insects, they must be raised specifically for human food following current good manufacturing practices (CGMP, 21CFR 110). Insects raised for animal or pet food cannot be diverted to human food. They cannot be "wildcrafted" (collected in the wild) and sold as food due to the potential of carrying diseases or pesticides.

The manufacturer also needs to demonstrate the "wholesomeness" of the product. There is a growing body of scientific literature that people who are allergic to shellfish (shrimp, lobster, etc.) may also be allergic to insects either as food or as adulterants in foods."

Fig. 3 Standard response from the United States Food and Drug Administration regarding the use of insects marketed as a food (2013)

regulatory compliance and product safety as early as 2010, at that time there was little practical understanding of how insects could or should be regulated as a food in Canada and the US. In 2013 a small group of American insect farmers and insect product makers secured the first clear guidance from the FDA (Fig. 3), outlining what steps could be taken to have a safe and wholesome insect food product. Notably, the document specified that insect marketed for human consumption must be farmed specifically for human consumption; that insect food products must be processed, packaged and transported in accordance with current good manufacturing practices (cGMP); and must include a warning label for crustacean or shellfish allergies for consumer safety. This was key for the industry to align expectations of what constituted a "Human consumption-grade insect," and to have a clearer example of regulatory compliance with which to work from. For the next 2 years, many in the industry worked under the impression that insects would eventually have to be approved as Generally Recognized As Safe (GRAS) by the FDA to become a more mainstream product, as well as to secure key investments and distribution partnerships reticent to work with insects without clearer regulatory guidelines. However, in her 2016 Food Navigator story about edible insects, "Edible Insects: Beyond the Novelty Factor," Elaine Watson interviewed an FDA spokesperson who encapsulated the discussion even more succinctly, stating that insects, if they are farmed and

processed as food, are food. They also stated that manufacturers using whole insects or milled powders made from whole insects would not be required to go through the GRAS process provided they comply with the pre-market provisions of the Food, Drug and Cosmetics act. At this point Health Canada has also provided clear guidance on pre-market provisions to insect product makers for selling insect products to consumers.

7.2 Investments in the Food Insects Industry

As of January 2017, several insect CPGs have gone beyond crowdfunding, and raised successful funding rounds from VC and Angel Investors. Chapul was the first company to be funded, when a 2014 appearance on the popular TV show Shark Tank (season 5, episode 21) secured serial investor Mark Cuban's investment of \$50,000 into the company. That same year, Exo received initial Seed Funding through serial investor Tim Ferriss. (<http://fortune.com/2014/07/18/bugs-in-your-protein-bar-are-edible-insects-the-next-food-craze/>). In 2015, Entomo Farms in Canada raised \$1million in a Series A from venture capital investors Hedgewood. Also in 2015, Bitty Foods raised \$1.2 million in Seed Funding from Florence Group and Arielle Zuckerberg (sister of Facebook founder Mark Zuckerberg) and Tiny Farms raised an undisclosed amount of funding from Arielle Zuckerberg, Investors Circle, and former Bain & Company consultant Drew Fink. In 2016, Exo closed a Series A funding round of \$4million with investors from AccelFoods, the Collaborative Fund, Tim Ferriss, endurance athlete Amelia Boone and celebrity rapper Nas. (<https://www.entrepreneur.com/article/271951>) As of the time of writing, Chirps Chips recently appeared on Shark Tank in January 2017, securing a \$100,000 investment from Mark Cuban. Numerous companies have received grant funding from the USDA, including All Things Bugs (now Griopro), who also secured initial funding through The Bill and Melinda Gates Foundations, though continued funding was declined. Most recently in 2016 BugEater Foods in Nebraska received a USDA grant to explore using insect ingredients in staple foods like pastas and noodles. Additionally, many companies have also won pitch competitions or been part of accelerator or incubator programs garnering prizes in funding and resources to help continue their work.

7.3 Market Trends

While the majority of insect based food products are still only available direct-to-consumer through websites, more companies have been able to secure distribution through online aggregation channels and physical retail locations since 2014 (Fig. 4). Many products can now be found through online giants like Amazon and insect food aggregators like EntoMarket, and the more established consumer product brands like Chapul, Exo, Bitty Foods and Chirps, as well as insect

North American Companies With Insect-Based Food Products On The Market (2017)

- Aspire Food Group (USA) DBA as Aketta
- Bitty Foods (USA)
- C-Fu Foods (Canada) DBA as One Hop Kitchen
- Chapul (USA)
- Cowboy Cricket Farm (USA)
- Craft Crickets (USA)
- CricketFlours (USA)
- Crik Nutrition (Canada)
- Critter Bitters (USA)
- Don Bugito (USA)
- Entomo Farms (Canada)
- EntoMarket DBA as EntoVita (USA)
- Exo (USA)
- Hotlix (USA)
- Incredible Foods (USA)
- Jurassic Snacks (USA)
- Gran Mitla (Mexico)
- Lithic Nutrition (USA)
- Merci Mercado (Mexico) DBA as Mercado Mio
- Naak Bar (Canada)
- Ozark Fiddler Farm (USA)
- Rocky Mountain Micro Ranch (USA)
- Sal De Aqui (Mexico)
- Seek Foods (USA)
- Seginus Farms (USA)
- Six Foods (USA) DBA as Chirps
- Tomorrow's Harvest Farms (USA)
- Uka Proteine (Canada)

Fig. 4 North American companies marketing insect products to consumers

ingredient brands like Entomo Farms, are making their way into grocery store shelves. Insect products can now be found in grocery and natural food chains like Sprouts Farmers Market, Mom's Organics, Wegman's, Vitamin Cottage/Natural Grocers and Publix Super Markets (Gustafson 2016).

In 2016, CEO of Pepsi Co. Indra Nooyi stated:

"[Experts] said the hottest thing is eating crickets. I am not talking about the game cricket, I am talking about crickets! In chips. And I am a vegetarian, I am not eating any cricket chips. But they said if you want a high protein source, there is a series of products being launched with crickets," Nooyi stated. "One year, three year, five year, ten year: we have different people looking at different horizons, because if you believe in the ten year horizons and what we are seeing, some of the weirdest food and beverage habits are showing up." (Troitino 2016)

8 Media and Public Exposure

These startups didn't go unnoticed by the popular media either. There has recently been a massive shift in the way the press positions edible insects as a potential part of fixing our broken food system. Beginning in 2012, but increasing exponentially after the 2013 report "Insects to Feed the World," report by the FAO, prominent publications in print, radio, TV and online media have recognized the potential for insects to feed a growing population, not as a stunt or gag, but as a potential resource that's been ignored. The phrase "Edible Insects" was found in 728 news articles in 2010 and rose to 6070 articles in 2016. The term "Entomophagy" rose from 34 news articles in 2010 to 1230 articles in 2016 (Shockley et al. 2017). Numerous organizations and individuals promote education and outreach to the public around edible insects, including University student organizations like the University of Georgia Athens BugDawgs; nonprofits and educators like Little Herds, MealFlours, Ento Education, educator James Ricci, Daniella Martin's Girl Meets Bug blog; educational resources like Megan Curry's Open Source "Ento.Ed," middleschool mealworm farming curriculum; and Don Peavy's "Buggin' Out with ChefPV," kids education YouTube video series.

8.1 Chefs Lend Credibility

As more people began to be curious about eating insects, chefs who had been serving insects began to receive a share of the spotlight. When people eat at these restaurants, they know and trust that the chef will make the food delicious, and are more receptive to insect cuisine when it's on the menu. Chefs are also taking insect ingredients and using them in innovative and exciting new ways, transcribing the mysteries of how to best use insect ingredients for future home cooks. A great example is Chef Jose Andres, whose Oyamel has been serving chapulines tacos in Washington DC for years, priming the palates of tomorrow in a notably respected setting. Another example is from Austin, Texas where chef Charles Zhou of Barley Swine, known for their fermentation and pickling, has fermented crickets instead of soybeans to create a soy-less, umami-rich and earthy cricket-miso. Other examples include La Condesa and Dai Due in Austin; Linger in Denver; Sticky Rice in Chicago; Typhoon in Santa Monica; Sushi Mazi in Portland; Toloache, Mezcal and Black Ant in New York; El Rey and La Mezcaleria in Vancouver; El Catrin and Cookie Martinez in Toronto; El Cardenal, Azul Condesa or Pujol in Mexico City.

8.2 Celebrities Make Eating Bugs Cool

In the last 5 years the edible insect industry has seen a growing number of popular personalities, like athletes, actors/actresses, musicians, thought-leaders and public figures making public declarations about the benefits of eating insects. Prior to that,

many entomophagy advocates like David George Gordon (aka The Bug Chef), David Gracer and Florence Dunkel had shared edible insects with talk show hosts such as The Tonight Show with David Letterman and The Colbert Report with Stephen Colbert. As more public figures try their first bugs, or even openly embrace adding insects to our diets, the public at large is becoming more receptive to the idea. This is not surprising, as many celebrities are seen as aspirational figures, desirable of emulation; if someone I admire and aspire to be like is open to eating insects, maybe I should give it a try too. Musician Questlove showcases insects as a food ingredient in his 2016 book, "Something to Food About." Actor and former American football player Terry Crews features in a 2016 BuzzFeed video about cricket protein shakes, claiming "That's the best protein in the world!" Former President of the United States of America, Barack Obama, even discussed eating insects as a small boy in Indonesia in his book, "Letters From My Father." Other prominent celebrities, musicians and athletes who have tried edible insects as of early 2017 include: Actors/Actresses Salma Hayek, Don Cheadle, Angelina Jolie, Ellen DeGeneres, Christian Slater, Tituss Burgess and Anna Fariss, as well as singer Katy Perry, rapper Nas, endurance athlete Amelia Boone, Los Angeles Lakers Basketball player Metta World Peace and many more.

8.3 Getting Past the Ick Factor

Many American and Canadian consumers still have negative reactions towards the idea of entomophagy. Many of the advocates for edible insects use existing examples of Western food trends changing to justify the idea that insects will eventually be a normal food for people all across North America. Sushi is usually the prime example, with lobster, offal, Chinese food, kale and quinoa also used as examples of changing dietary preferences. Many educators, this co-author included (Allen), such as teachers, professors, museums, universities and nonprofit organizations like Little Herds have proposed that by introducing children to insect cuisine at a young age, those children grow up without the cultural taboo strongly entrenched, and are more open to entomophagy. This is purely based on anecdotal evidence from stakeholders and educators in the edible insects industry working in communication and outreach roles. Unfortunately, at the time of writing, no studies on children's "ick factor" related to edible insects could be found. Younger generations are also more receptive to new and unusual foods, and are usually more receptive to the idea of eating insects than older generations. As entomophagy continues to garner positive exposure in the media, more destination restaurants or acclaimed chefs serve them and more diverse products continue to gain market traction, the overall public perception will continue to shift towards acceptance and normalization.

9 Edible Insects in the Future

In early 2017 the Seattle Mariners baseball stadium began serving chapulines grasshoppers through a concession stand run by local restaurant, Poquito. For four nights in a row the stadium sold out of chapulines, creating much fanfare on sports networks and across the internet. They were forced to limit the number of orders available per game to meet demand, and chose 312 orders as the cap to celebrate Mariners great Edgar Martinez's lifetime batting average of 0.312. Isolated events like this bear proof to a broader movement towards acceptance and inclusion into the diets of (at least some) some of the public who traditionally would not have eaten insects in North America.

With the 2016 founding of the NACIA, the North American edible insects industry has their first trade association focusing on consumer education and research prioritization. More chefs are adding insects to their menus; more farmers are growing insects for food; more product makers are using insects in novel and unique ways and the public is increasingly more aware of the costs associated with their food choices more generally and the potential for insects as a nutritious food source more specifically. These authors anticipate the continued, if not accelerated, growth of the industry into more and more consumers' daily lives. As farming and processing systems are made more efficient, and insect ingredients' applicability is better understood and further explored, the price for insect products will continue to fall towards a more competitive cost comparison with traditional protein sources, making these twenty-first century livestock products not only desirable, but attainable for the average consumer.

References

- Aldrich J (1921) *Coloradia pandora* Blake, a moth of which the caterpillar is used as food by mono Lake Indians. *Ann Entomol Soc Am* 14:36–38
- Berenbaum MR (1996) *Bugs in the system: insects and their impact on human affairs*. Basic Books, New York
- Brickell J (1737) *The natural history of North Carolina*. Johnson Publishing Company, Murfreesboro
- Burgh RF, Scoggin CR (1948) *Archaeology of Castle Park, Dinosaur National Monument*. University of Colorado Press, Boulder
- Carr LG (1951) Interesting animal foods, medicines, and omens of the eastern Indians, with comparisons to ancient European practices. *J Wash Acad Sci* 41(7):229–235
- Christenson AJ (2007) *Popol Vuh: sacred book of the Quiché Maya people*. Mesoweb Publications, University of Oklahoma Press, Norman
- Cohen JH (2004) *The culture of migration in southern Mexico*. University of Texas Press, Austin
- Costa-Neto EM, Ramos-Elorduy J (2006) Los insectos comestibles de Brasil: etnicidad, diversidad e importancia en la alimentación. *Boletín Sociedad Entomológica Aragonesa* 38:423–442. Espeitx E
- Ebeling W (1986) *Handbook of Indian foods and fibers of arid America*. University of California Press, Berkeley
- Egan HR (1917) *Pioneering the west, 1846 to 1878: Major Howard Egan's diary. Also thrilling experiences of pre-frontier life among Indians, their traits, civil and savage, and part of autobiography, inter-related to his Father's*. Skelton Publishing Company, Salt Lake City

- Felt E (1918) Caribou warble grubs edible. *J Econ Entomol* 11:482
- Grieshop JI (2006) The envios of San Pablo Huixtepec, Oaxaca: food, home, and transnationalism. *Hum Organ* 65(4):400–406
- Gustafson K (2016) Would you eat crickets? Some grocery stores are betting on it. *Forbes* <https://www.forbes.com/forbes/welcome/?toURL=https://www.forbes.com/sites/katherinegustafson/2016/09/01/would-you-eat-crickets-some-grocery-stores-are-betting-on-it/&refURL=https://www.google.com/&referrer=https://www.google.com/>
- Hammer UT (1986) Saline lake ecosystems of the world, vol 59. DR W. Junk Publishers, Dordrecht
- Hearne S, Tyrrell JB (1795) A journey from prince of Wales's fort in Hudson's bay to the Northern Ocean, vol 445. The Champlain Society, Toronto
- Jongema Y (2017) Worldwide list of edible insects. https://www.wur.nl/upload_mm/8/a/6/0fdcf700-3929-4a74-8b69-f02fd35a1696_Worldwide%20list%20of%20edible%20insects%202017.pdf
- Leonard WR (2003) Food for thought. *Sci Am* 13:62–71
- Lesnik JJ (2017) Not just a fallback food: global patterns of insect consumption related to geography, not agriculture. *Am J Hum Biol* 00:e22976
- Madsen DB, Schmitt DN (1998) Mass collecting and the diet breadth model: a Great Basin example. *J Archaeol Sci* 25(5):445–455
- Morgan LH (1877) *Ancient Society*. World Publishing: New York.
- Orr PC (1952) Preliminary excavations of Pershing County caves. Nevada State Museum, Department of Archeology, Carson City
- Ramos-Elorduy J (2009) Anthro-entomophagy: cultures, evolution and sustainability. *Entomological Research* 39(5):271–288
- Ramos-Elorduy J, Pino J (1998) Insectos comestibles del estado de México y determinación de su valor nutritivo. *Anales del Instituto de Biología, UNAM* 69:65–104
- Ramos-Elorduy J, Pino Moreno JM (2004) Los Coleoptera comestibles de México. *An Inst Bio* 75(1):149–183
- Ramos-Elorduy J, Viejo Montesinos JL (2007) Los insectos como alimento humano: Breve ensayo sobre la entomofagia, con especial referencia a México. *Bol R Soc Esp Hist Nat Sec Biol* 102(1–4):61–84
- Ramos-Elorduy, Moreno JMP, Prado EE, Perez MA, Otero JL, de Guevara OL (1997) Nutritional value of edible insects from the state of Oaxaca, Mexico. *J Food Compos Anal* 10(2):142–157
- Ramos-Elorduy J, Costa NEM, Ferreira dos Santos J, Pino MJM, Landero-Torres I, Ángeles CSC, García PA (2006) Estudio comparativo del valor nutritivo de varios coleoptera comestibles de México y *Pachymerus nucleorum* (fabri- cius, 1792) (bruchidae) de Brasil. *Inter- ciencia* 31(7):512–516
- Ramos-Rostro B, Figueroa-Colin S, Olguin-Arredondo H (2009) Extracción de hormigas miel- eras (*Myrmecystus Mexicanus*): una reseña sobre el trabajo de campo, en Santo Domingo, Axapusco, Estado de Mexico. *Culinaria revista virtual gastronomica* (5):21–34
- Russell F (1898) *Explorations in the far north*. University of Iowa, Iowa City
- Sandel A (1715) Memorandum. *Mitchell and Miller's Medical Repository* 4:71
- Schrader J, Ooninx DGB, Ferreira MP (2016) North American entomophagy. *J Insects Food Feed* 2(2):111–120
- Shockley M, Allen RN, Gracer D (2017) Product development and promotion. In *Insects as food and feed: from production to consumption*. Wageningen Academic Publisher.
- Steward JH (1943) *Culture element distributions: XXIII*. Berkeley, Northern and Gosiute Shoshoni, University of California Press
- Sutton MQ (1988) *Insects as food : aboriginal entomophagy in the Great Basin*. Ballena Press, Menlo Park
- Sutton MQ (1995) Archaeological aspects of insect use. *J Archaeol Method Theory* 2(3):253–298
- Thrusell E (2016) A recipe for identity: food and culture in Oaxaca, Mexico. University of Adelaide, Adelaide
- Troitino C (2016) Why Pepsi's CEO believes that bugs are the protein of the future. *Forbes* <http://www.forbes.com/sites/christinatroitino/2016/10/31/why-pepsis-ceo-believes-that-bugs-are-the-protein-of-the-future/#419a01e52211>

- Van Huis A, Van Itterbeeck J, Klunder H, Mertens E, Halloran A, Muir G, Vantomme P (2013) Edible insects: future prospects for food and feed security, vol 171. Food and Agriculture Organization of the United Nations (FAO). Rome
- Wakefield EG, Dellinger SC (1936) Diet of the bluff dwellers of the Ozark Mountains and its skeletal effects. *Ann Intern Med* 9(10):1412–1418
- Wilken GC (1970) The ecology of gathering in a Mexican farming region. *Econ Bot* 24(3):286–295
- Yarnell RA (1974) Intestinal contents of the salts cave mummy and analysis of the initial salts cave flotation series. In: Watson PJ (ed) *Archeology of the mammoth cave area*. Academic Press, New York, pp 109–112